Hot Mix Asphalt Railway Trackbeds:
Trackbed Materials, Performance Evaluations, and Significant Implications

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- Debated between cement and asphalt
- Asphalt performed better – opted for use on all high-speed passenger lines

- 12 cm of asphalt with 200 MPa modulus
- 30 cm of super compacted subgrade with 80 MPa modulus
- 35 cm of ballast on top
New Railway Roadbed Design

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When laying track on earth structures, roadbed performance is extremely important for controlling track settlement and dynamic deflection. In order to meet roadbed performance demands in Japan, concrete roadbed is used for slab track (Fig. 1), and asphalt roadbed is used for ballasted track (Fig. 2); this structure is also standard for the Shinkansen bullet train. The roadbed design methods are described in the “Design Standard for Railway Structures (Earth Structures).” In the January 2007 revision to this design standard, a performance based design method was introduced.

As the previous Design Standard for Railway Structures (Earth Structures) was based on specifications, the thickness of each layer of the roadbed design was specifically defined. With the performance based design method, however, it has become possible for the designers to design roadbed thickness to satisfy roadbed performance requirements. Specifically, by considering the fatigue life related to the number of trains, a method of designing thickness according to the importance of a particular section of track is described. Also, while the previous design concept was not consolidated with regard to a concrete roadbed for slab track or an asphalt roadbed for ballasted track, with this revision the roadbed design methods have been grouped together systematically.

With the new design standard, the earth structure performance rank for the relevant track is determined by the relative importance of the section of track and the track type. When designing the roadbed, a type of roadbed is selected to suit each of the various performance ranks. For performance rank I, concrete roadbed or asphalt roadbed for ballastless track is selected; for performance rank II, asphalt roadbed for ballasted track is used; and for performance rank III, crushed stone roadbed for ballasted track is selected. After the type of roadbed has been selected in this way, the roadbed structure design is carried out.

In the case of a concrete roadbed (Fig. 3), the following effects of train loads are checked for: displacement of the roadbed, breakage of the reinforced concrete base, fatigue damage, cracking, contraction, and thermal stresses. For asphalt roadbeds, the following effects of train loading are checked: displacement of the roadbed and fatigue damage of the asphalt mixture layer. In particular, in the case of an asphalt roadbed for ballasted track (Fig. 4), fatigue failure had not been considered in the previous design; however, this time a design method based on fatigue life has been introduced.

In this way, by systemizing roadbed design thinking to suit the design standard revision, and with the introduction of the performance-based design method, flexible design to suit the importance of the track section has now been made possible.
• With the new design standard, the earth structure performance rank for the relevant track is determined by the relative importance of the section of track and the track type. When designing the roadbed, a type of roadbed is selected to suit each of the various performance ranks.

• Performance Rank 1 – concrete roadbed or asphalt roadbed for ballastless track is selected

• Performance Rank 2 – asphalt roadbed for ballasted track is used

• Performance Rank 3 – crushed stone roadbed for ballasted track is selected.

• After the type of roadbed has been selected in this way, the roadbed structure design is carried out.
Germany

- German Getrac - ballastless track
- Track Panels are directly supported by asphalt
- Two Types: Getrac A1 and Getrac A3
Strengthens Trackbed Support

Waterproofs Underlying Roadbed

Confines Ballast and Track

8 to 12 in.

5 to 6 in.

12 ft.
Dense-Graded Highway Base Mix
1 – 1 ½ in. Maximum Size Aggregate
Asphalt Binder +0.5% above Optimum
Low to Medium Modulus Mix, 1 - 3% Air Voids
Pressure Cell

- Geokon Model 3500-2
- 9 in. Diameter
- Strain Gage
- Snap-Master
- Thermistor

Cell Placement on Asphalt
Pressure Cell Measurement Configuration
Empty Coal Train at Conway

P-Cell 209 on 5 in. HMA Layer

Initial 5 Cars

4 6-Axle Locos
Reduction of Dynamic Stresses

![Graph showing stress over time for 8 in. HMA surface and Subgrade surface.]
Loaded Coal Truck at Lackey

P-Cell 510 Beneath High Rail and Tie

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Rear Tires of Tractor of a 151,000 lb Loaded Coal Truck on Concrete Crossing of Kentucky Coal Terminal, Mile Post 6.6. May 25, 2004

9842 lb

135 psi

72.93 in\(^2\)

Force vs. Frames

Pressure vs. Frames
Front Tire of a CSXT Suburban on Asphalt Parking Lot in Ashland Oil Company.

May 25, 2004

1652 lb

75 PSI

22.15 in^2

Force vs. Frames

Pressure vs. Frames
Top of Asphalt Temperature vs Time

Richmond

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Legend:
- Black line: 7-Day Average Ambient Temp
- Blue line: Top of Asphalt Temperature
- Red line: 7-Day Max Air Temp
- Red line: 7-Day Min Air Temp
Tests and Evaluations

Trackbed Materials
• Ballast

• Subgrade
  Moisture Content
  Proctor Moisture-Density Classification
  CBR

• Asphalt
  Core Tests
  Recovered Binder Tests

1998 - 2007
Core Drilling
Core Drilling
Core Drilling
Soil Tests
Moisture Content Test
between 1998 and 2007
Tests After Coring

OK City Yard, New Subgrade

Conway, KY Old Roadbed
Changes in Optimum Subgrade Moisture Contents Between 1998 and 2007

![Bar chart showing changes in optimum moisture content between 1998 and 2007 for various locations. The chart includes data for Select Subgrade Guthrie, OK, Clay Subgrade OK City, OK, Clay Subgrade Quinlan, OK, Silt Subgrade Quinlan, OK, Subballast Hoover, TX, and Subgrade Hoover, TX. The changes are expressed as percentages.]}
Relationships for Roadbed/Subgrade In-Situ and Optimum Moisture Contents

\[ y = 1.248x - 3.513 \quad R^2 = 0.914 \]
\[ y = 1.062x - 1.208 \quad R^2 = 0.938 \]

\[ y = 1.148x - 2.267 \quad R^2 = 0.918 \]
Classification Tests
## Unified Soil Classification

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<td>Silty sand</td>
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<td>Sandy silt</td>
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<td>Clayey sand</td>
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CBR Test
Comparison of 1998 and 2007 unsoaked and soaked CBR test values for the roadbed/subgrade.
Subgrade Findings/Discussions

- In-situ Moisture Contents
  - Remain Consistent Over Time
  - Compare Favorably With Optimum
- Assume Unsoaked, Optimum Condition
- Bearing Capacity Remains At or Near Optimum
- Wide Range of Subgrades Evaluated
- Minimum Loading Induced Stress on Subgrade
ASPHALT TESTS

RECOVERED ASPHALT

CORES
Resilient Modulus

25$^\circ$C (77$^\circ$F)
Resilient Modulus versus Age of Asphalt
Penetration

Absolute Viscosity
Penetration and Absolute Viscosity Versus Age of Asphalt
Values for Railroad and Lab Cured Asphalt Cores (2007 Data)
Dynamic Shear Rheometer
25°C (77°F)
Dynamic Shear Rheometer

\[ G^*/\sin \delta \]
Asphalt Findings/Discussions

- Resilient Modulus Values are Intermediate in Magnitude – Typical of Unweathered Asphalt Mixes
- Asphalt Binders do not Exhibit Excessive Hardening (brittleness), Weathering, Deterioration or Cracking
- Asphalt is Insulated from Environmental Extremes
- Asphalt Experiences Minimal Loading Induced Stress
- Conditions Influencing Typical Failure Modes Experienced by Asphalt Highway Pavements don’t Exist in Asphalt Railroad Trackbeds
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